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RESEARCH MEMORANDUM

WIND-TUNNEL INVESTIGATION AT HIGH SUBSONIC SPEEDS OF THE EFFECT OF SPOILER PROFILE ON THE LATERAL CONTROL CHARACTERISTICS OF A WING-FUSELAGE COMBINATION WITH QUARTER-CHORD LINE SWEPT BACK 32.6°

AND NACA 65A006 AIRFOIL SECTION

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH MEMORANDUM

WIND-TUNNEL INVESTIGATION AT HIGH SUBSONIC SPEEDS OF THE EFFECT OF SPOILER PROFILE ON THE LATERAL CONTROL CHARACTERISTICS OF A WING-FUSELAGE COMBINATION WITH QUARTER-CHORD LINE SWEPT BACK 32.6° AND NACA 65A006 AIRFOIL SECTION

By Harold S. Johnson

SUMMARY

An investigation was made in the Langley high-speed 7- by 10-foot tunnel through a Mach number range from 0.39 to 0.89 to determine the effect of spoiler profile on the lateral control characteristics of a wing-fuselage configuration. The wing had an NACA 65A006 airfoil section, an aspect ratio of 4, and a taper ratio of 0.6, and the quarter-chord line was swept back 32.6°. Rolling- and yawing-moment data were obtained through an angle-of-attack range from 0° to about 8° for each of four 49.7-percent-semispan inboard spoilers located on the 70-percent-chord line.

The data indicated that spoilers having a front surface which produces an abrupt break in the airfoil surface are slightly more effective in producing rolling moment than are spoilers having a ramp-type forward surface. For the four spoilers investigated, the rolling-moment coefficients generally increased with Mach number.

INTRODUCTION

The use of spoilers as lateral-control devices on both swept and unswept wings has been the subject of numerous investigations and various profiles of spoilers have been tested. The purpose of the investigation reported herein was to make a direct comparison of the effect of spoiler profile by eliminating other variables such as wing plan form, spoiler span, and spoiler spanwise and chordwise location. Four inboard spoilers, each having a span of 49.7 percent of the wing semispan and

located on the 70-percent-chord line, were tested on the right semispan of an aspect-ratio-4, taper-ratio-0.6 wing having an NACA 65A006 airfoil section parallel to the fuselage center line and quarter-chord-line sweepback of 32.6°. The spoiler profiles investigated were a right-angle spoiler, forward- and rearward-hinged flap-type spoilers, and a spoiler obtained by joining the forward- and rearward-hinged flap-type spoilers at the line of maximum projection. The investigation was made in the Langley high-speed 7- by 10-foot tunnel through a Mach number range from 0.39 to 0.89 and an angle-of-attack range from 0° to about 8°. Lift, drag, and pitching-moment data were obtained for the wing-fuselage combination without spoilers, and rolling- and yawing-moment data were obtained for the model with each of the four spoilers.

SYMBOLS AND COEFFICIENTS

The forces and moments measured on the model are presented about the wind axes which, for the conditions of these tests (zero yaw), correspond to the stability axes. The origin of the axes is at a longitudinal position corresponding to the quarter-chord point of the mean aerodynamic chord (fig. 1).

C_L lift coefficient, $\frac{\text{Lift}}{qS}$

C_D drag coefficient, $\frac{\text{Drag}}{qS}$

C_m pitching-moment coefficient, $\frac{\text{Pitching moment}}{qS\bar{c}}$

C_l rolling-moment coefficient resulting from spoiler projection, $\frac{\text{Rolling moment}}{qSb}$

C_n yawing-moment coefficient resulting from spoiler projection, $\frac{\text{Yawing moment}}{qSb}$

q dynamic pressure, $\frac{1}{2}\rho V^2$, lb/sq ft

ρ mass density of air, slugs/cu ft

V free-stream velocity, ft/sec

M	Mach number
S	wing area, 2.25 sq ft
b	wing span, 3.0 ft
$\bar{c}$	mean aerodynamic chord of wing, $\frac{2}{S}\int_0^{b/2} c^2\,dy$, 0.765 ft
c	local wing chord, ft
α	angle of attack, deg
δ_s	spoiler projection, measured normal to wing surface, percent local wing chord

MODEL AND APPARATUS

A drawing of the model and a table of the geometric characteristics are given in figure 1. The profiles of the spoilers investigated are also shown in figure 1. The solid aluminum-alloy wing had an NACA 65A006 airfoil section parallel to the fuselage center line, a quarter-chord-line sweepback of 32.6°, an aspect ratio of 4, and a taper ratio of 0.6. The metal spoilers (referred to as spoilers 1 to 4) were attached to the upper surface of the right semispan with the projected edge located along the 70-percent-chord line (fig. 1). All the spoilers were 49.7 percent of the wing semispan in length and extended from the wing-fuselage junction $\left(0.139\,\frac{b}{2}\right)$ outboard to the $0.636\,\frac{b}{2}$ station.

The model was mounted on a sting-type support system in the Langley high-speed 7- by 10-foot tunnel. The sting was supported by a vertical strut located downstream from the test section. The system allowed the angle of attack of the model to be varied by longitudinally rotating the model and sting in a vertical plane about a point near the quarter-chord position of the wing mean aerodynamic chord. The forces and moments on the model were measured by means of an electrical strain-gage balance contained within the aluminum fuselage. The fuselage was a body of revolution and had a fineness ratio of 9.8. The fuselage ordinates are given in reference 1.

TESTS

The Mach number range was from 0.39 to 0.89, and the angle-of-attack range was from 0° to about 8°. Data were obtained for spoiler projections of -2.5, -5.0, and -10.0 percent of the local chord for spoilers 1, 2, and 3. Spoiler 4 was tested at only one projection (-10.0 percent c). The variation of Reynolds number (based on the wing mean aerodynamic chord of 0.765 foot) with Mach number is shown in figure 2.

CORRECTIONS

The test data have been corrected for jet-boundary effects by the method of reference 2. Blockage corrections based on the wing-fuselage combination without spoilers were applied to the data (ref. 3). No corrections for wing bending or twisting have been applied since these corrections as calculated from static loads on the wing were found to be negligible for the angle-of-attack range investigated. The spoilers were of rigid construction and did not deflect appreciably under airload. The drag coefficients were not corrected to account for the effects of the sting on the base pressure.

RESULTS AND DISCUSSION

The lift, drag, and pitching-moment characteristics of the model with the basic wing are shown in figure 3 for the various Mach numbers investigated. The variations of the lateral control characteristics with angle of attack for the various spoiler projections are given in figures 4 to 7 for the four spoilers investigated. The variations of the lateral control characteristics with spoiler projection are shown in figure 8 for spoilers 1 to 3 at Mach numbers of 0.59 and 0.86. A comparison of the variation of rolling-moment coefficient with Mach number for the four spoilers tested is given in figure 9 for a projection of -0.10c and $\alpha \approx 4^{\circ}$.

The aerodynamic characteristics of the basic model (fig. 3) are not discussed herein since a detailed analysis is presented in reference 1.

The data indicate that the rolling-moment coefficient resulting from spoiler projection for a given angle of attack and spoiler projection generally increased as the Mach number was increased with an abrupt increase in C_l being noted at a Mach number of about 0.8 for all the spoilers investigated (figs. 4 to 7 and 9). Generally, the rolling-moment coefficient increased as the angle of attack was increased from 0°

to 4° and decreased as α was further increased. The rolling-moment coefficients increased with spoiler projection for the range of $\delta_s = -0.025c$ to $-0.100c$ (figs. 4 to 8). At small projections, the forward-hinged flap-type spoiler (spoiler 2) was the least effective in producing rolling moment, and the rolling moments of this spoiler were negative at a projection of $-0.025c$ for some angles of attack at low Mach numbers (figs. 5 and 8). The curves of rolling-moment coefficient against spoiler projection (fig. 8) are not faired between 0 and $-0.025c$ since previous investigations (for example, ref. 4) have shown rather extreme nonlinearities in the rolling-moment-coefficient—spoiler-projection curves at low projections.

At a given angle of attack and spoiler projection, the rolling-moment coefficient of the right-angle spoiler (spoiler 1) was slightly greater than that of the other spoilers investigated. The rearward-hinged flap-type spoiler (spoiler 3) was slightly more effective than the forward-hinged flap-type spoiler (spoiler 2). At a projection of $-0.100c$, spoiler 4 was the least effective of the spoilers investigated and the rolling-moment coefficients resulting from projection of this spoiler were about 12 percent less than those of the right-angle spoiler for the Mach number range investigated (figs. 4, 7, and 9). The data indicate that spoilers having a front surface which produces an abrupt break in the airfoil surface (spoilers 1 and 3) are slightly more effective in producing rolling moment than are spoilers having a ramp-type forward surface (spoilers 2 and 4).

As expected, most of the yawing-moment coefficients resulting from spoiler projection were small or, if not small, had the same sign as the rolling-moment coefficient which is usually considered to be a favorable condition (figs. 4 to 8). The yawing-moment coefficients generally decreased with increasing angle of attack.

CONCLUDING REMARKS

A wind-tunnel investigation was made through a Mach number range of from 0.39 to 0.89 to determine the effect of spoiler profile on the lateral control characteristics of a wing-fuselage model. The results of the investigation showed that spoilers having a front surface which produces an abrupt break in the airfoil surface are slightly more effective in producing rolling moment than are spoilers having a ramp-type forward

surface. For the four spoilers investigated, the rolling-moment coefficients generally increased with Mach number.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., September 23, 1953.

REFERENCES

1. Wiggins, James W., and Kuhn, Richard E.: Wind-Tunnel Investigation of the Aerodynamic Characteristics in Pitch of Wing-Fuselage Combinations at High-Subsonic Speeds. Sweep Series. NACA RM L52D18, 1952.

2. Gillis, Clarence L., Polhamus, Edward C., and Gray, Joseph L., Jr.: Charts for Determining Jet-Boundary Corrections for Complete Models in 7- by 10-Foot Closed Rectangular Wind Tunnels. NACA WR L-123, 1945. (Formerly NACA ARR L5G31.)

3. Herriot, John G.: Blockage Corrections for Three-Dimensional-Flow Closed-Throat Wind Tunnels, With Consideration of the Effect of Compressibility. NACA Rep. 995, 1950. (Supersedes NACA RM A7B28.)

4. Fischel, Jack, and Ivey, Margaret F.: Collection of Test Data for Lateral Control with Full-Span Flaps. NACA TN 1404, 1948.

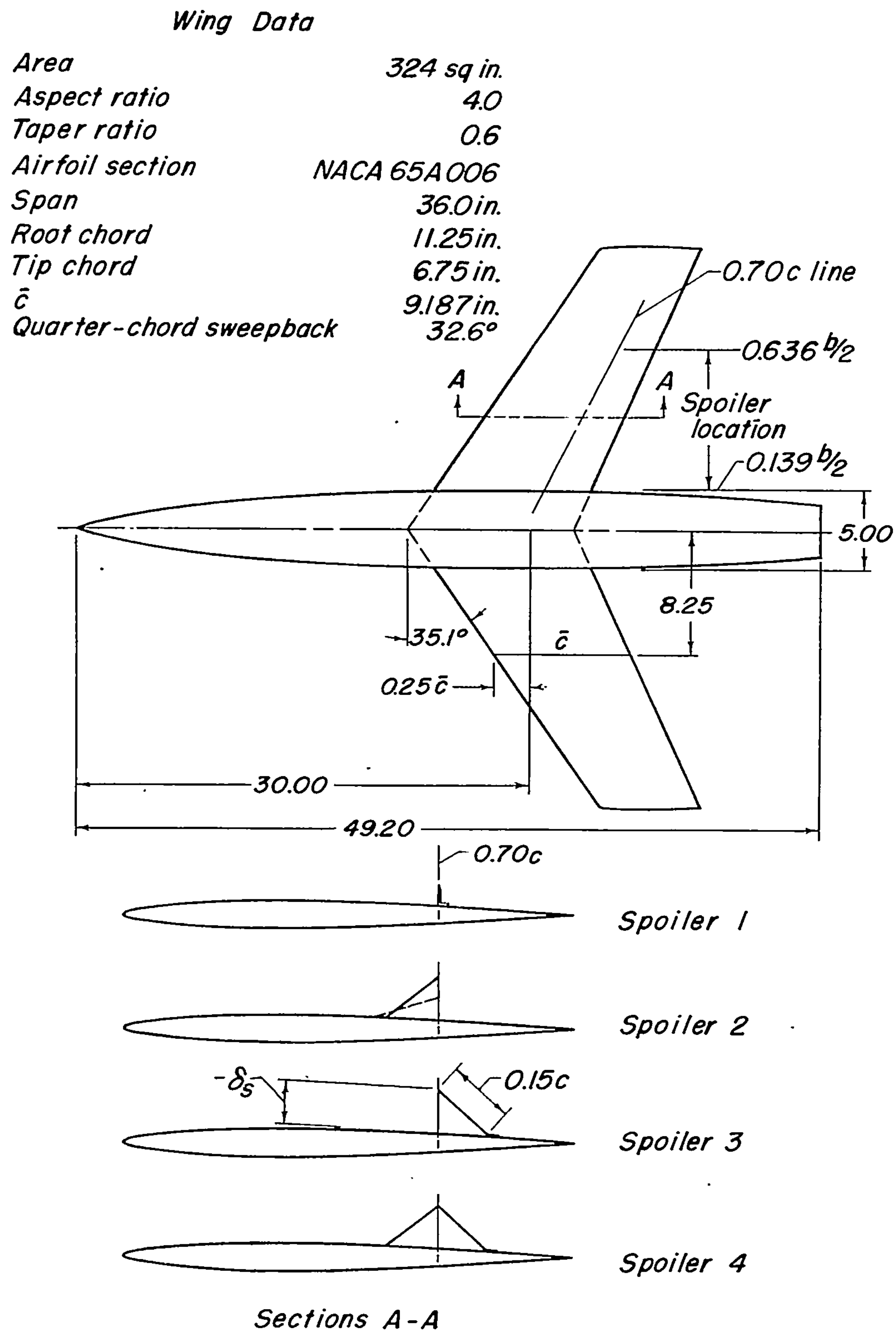

Figure 1.- Geometric characteristics of the wing-fuselage model and the various spoilers investigated. (All dimensions are in inches.)

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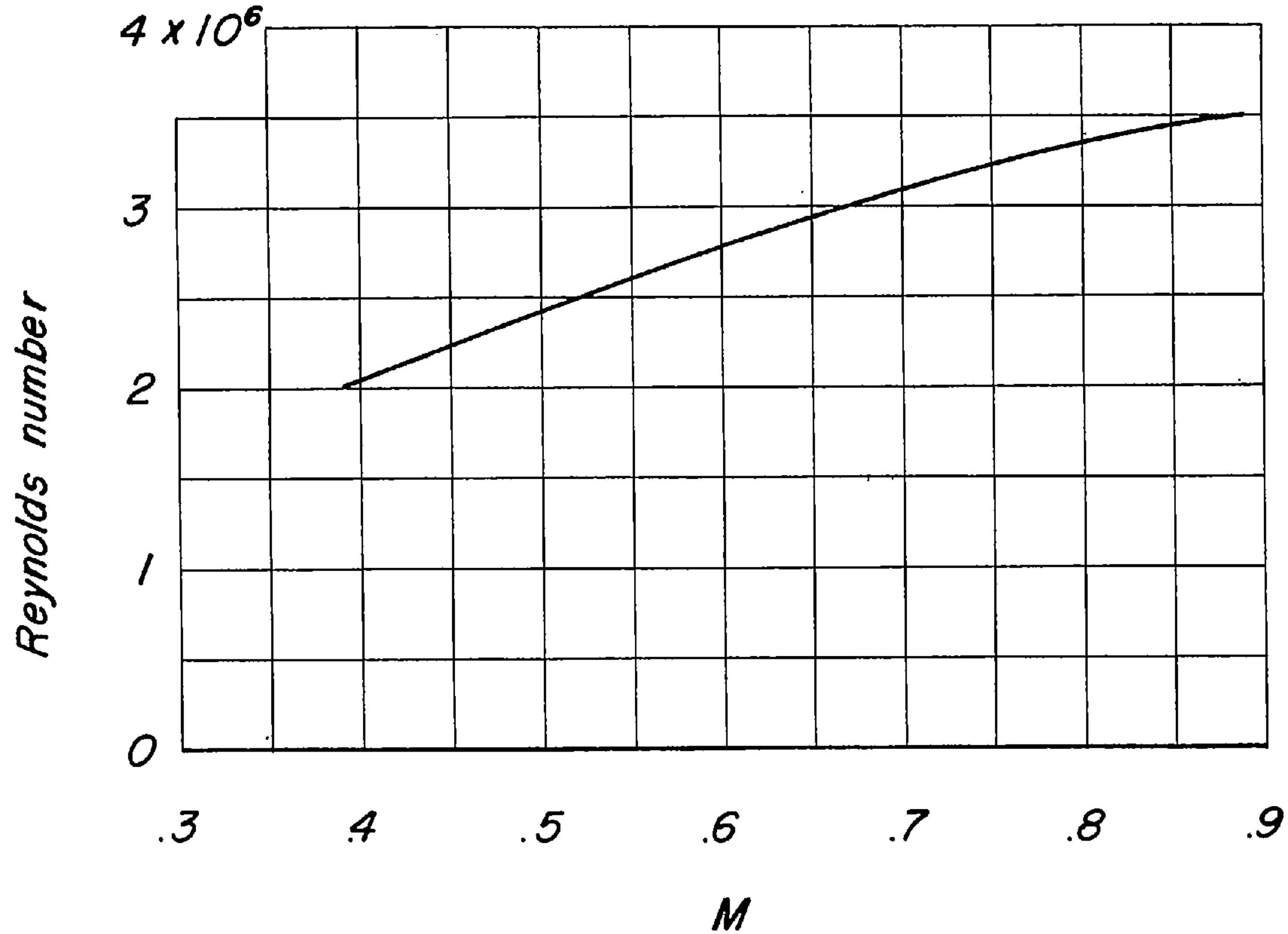

Figure 2.- Variation of Reynolds number (based on $\bar{c}$) with Mach number.

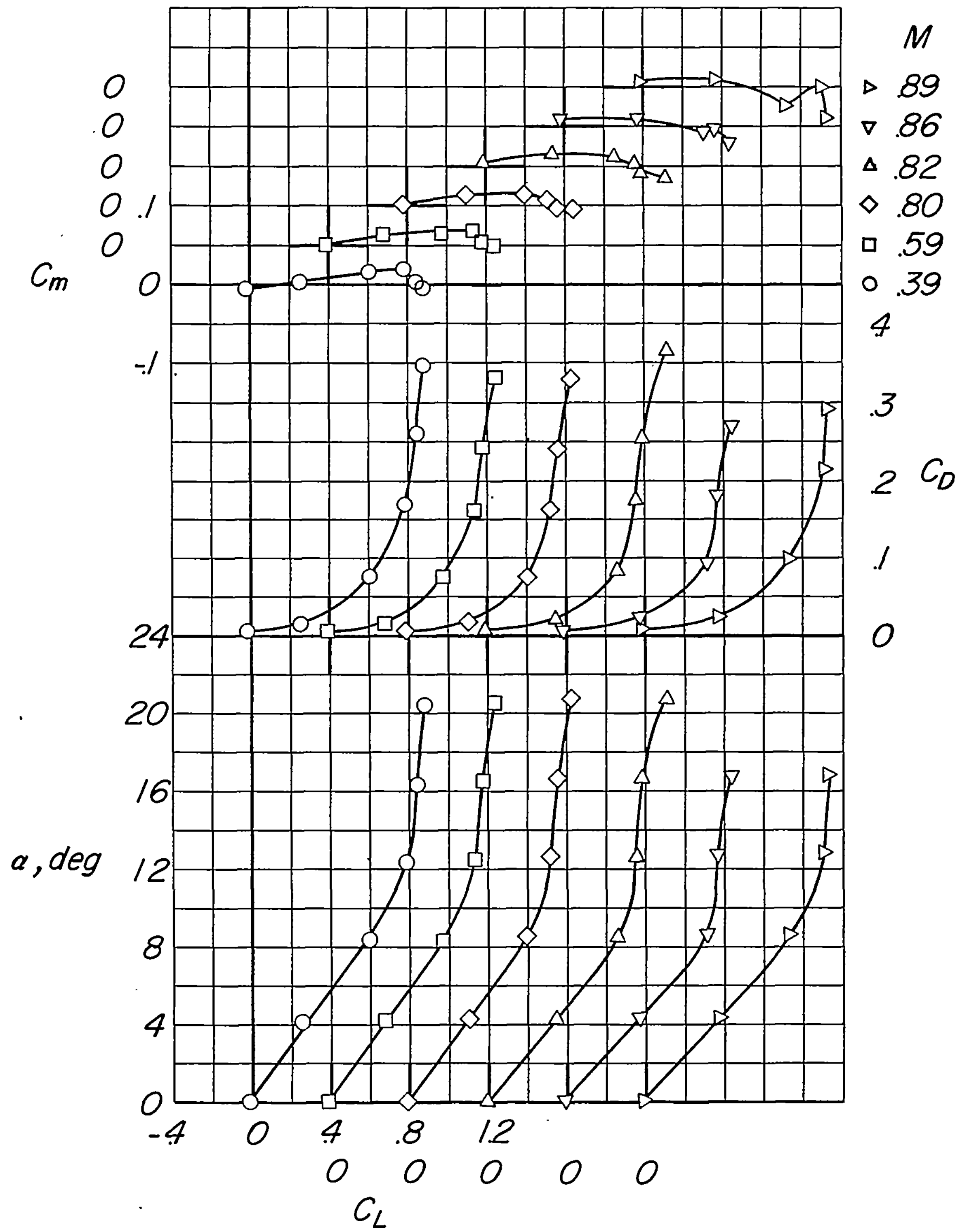

Figure 3.- Aerodynamic characteristics in pitch of the wing-fuselage model with the basic wing ($\delta_s = 0$).

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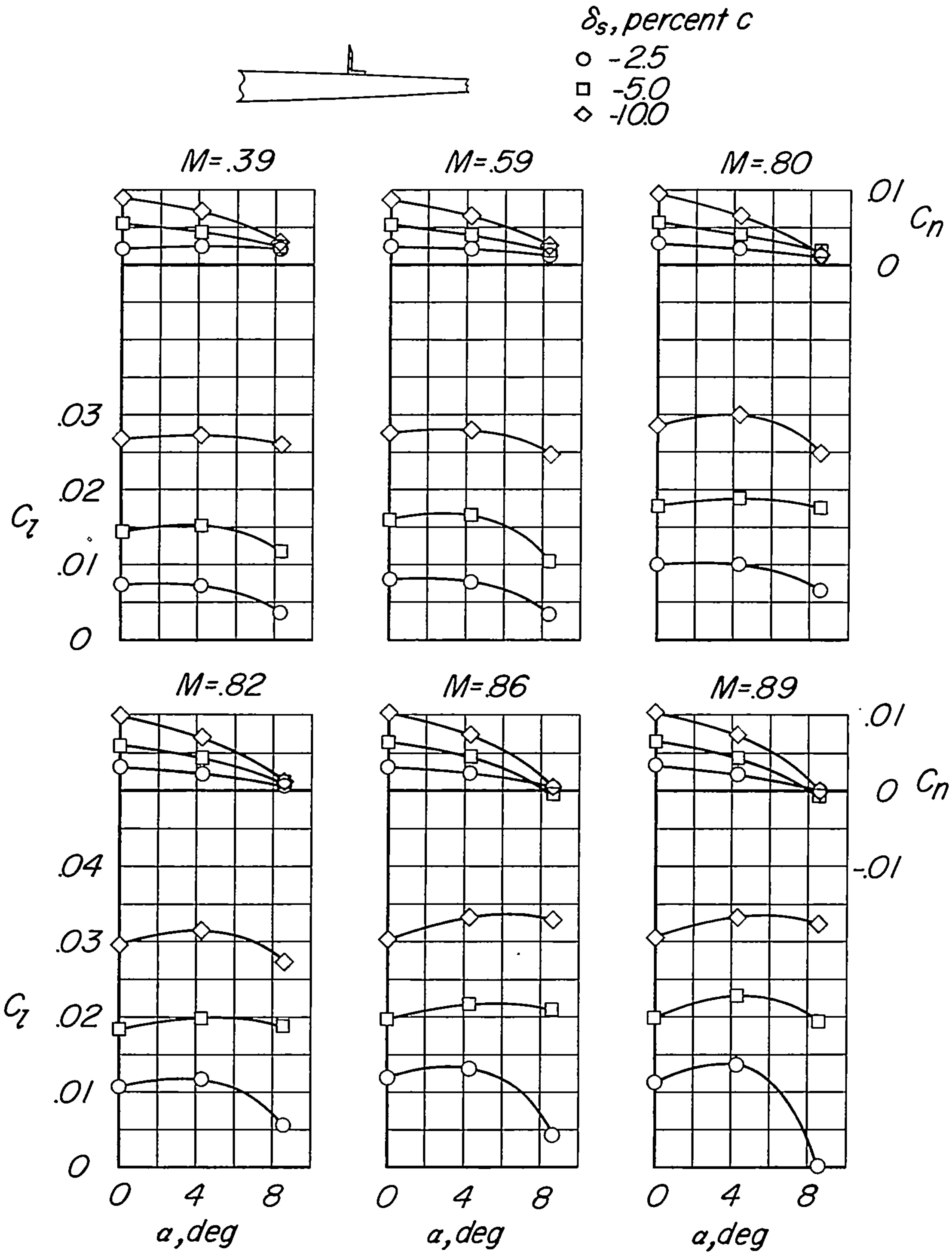

Figure 4.- Variation of the lateral control characteristics with angle of attack for various spoiler projections. Right-angle spoiler (spoiler 1).

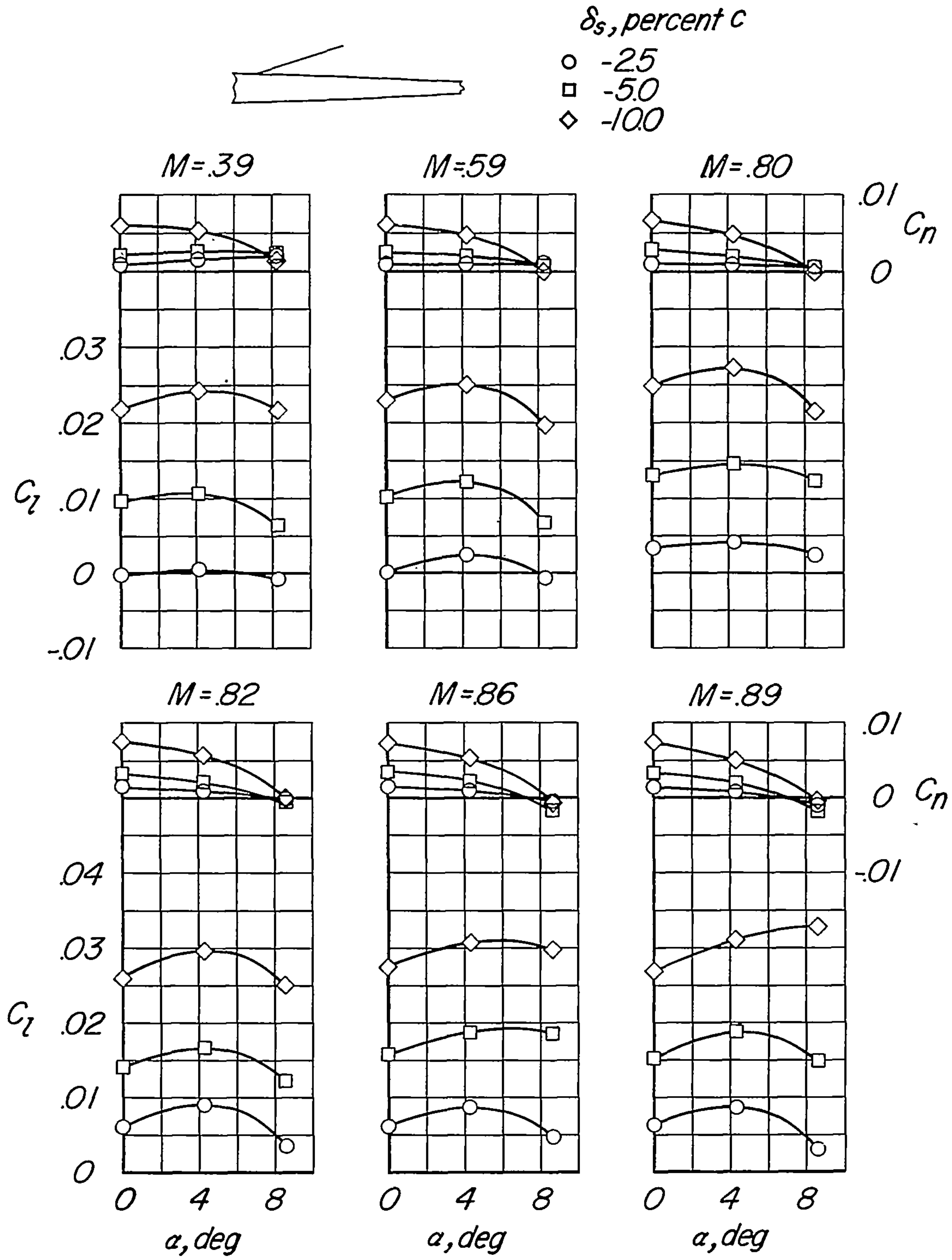

Figure 5.- Variation of the lateral control characteristics with angle of attack for various spoiler projections. Forward-hinged flap-type spoiler (spoiler 2).

[redacted]

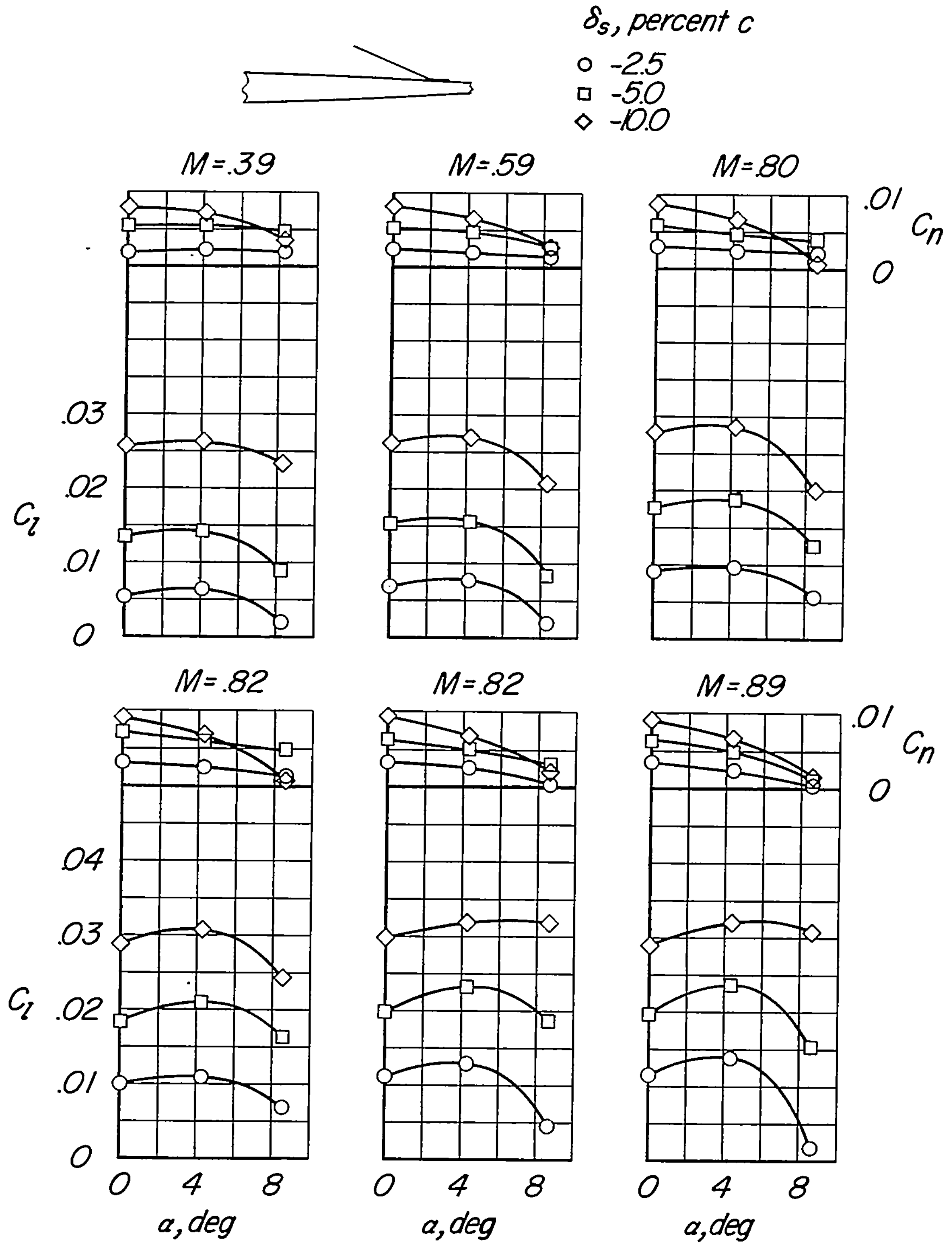

Figure 6.- Variation of the lateral control characteristics with angle of attack for various spoiler projections. Rearward-hinged flap-type spoiler (spoiler 3).

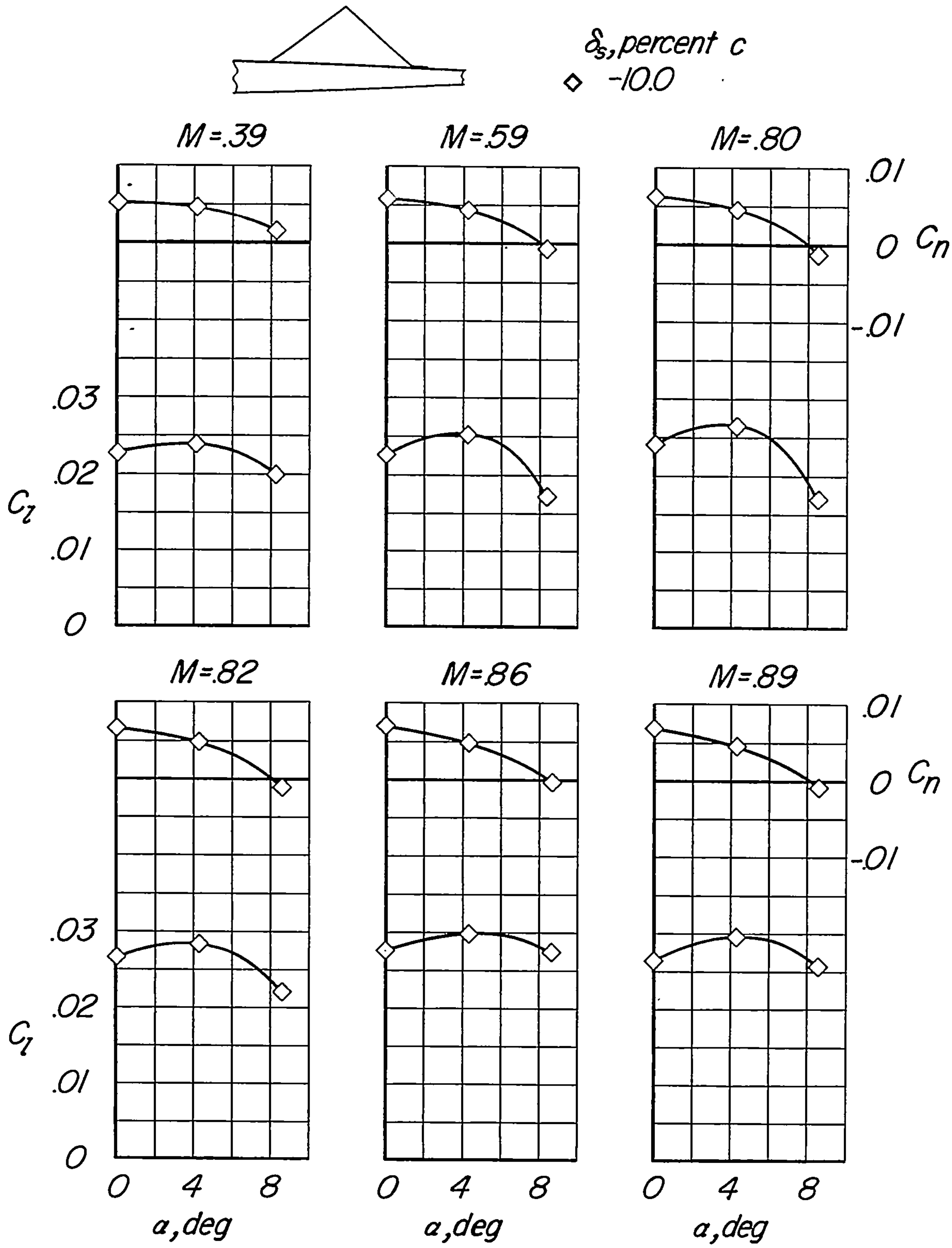

Figure 7.- Variation of the lateral control characteristics with angle of attack. Spoiler 4; δ_s = -10 percent c.

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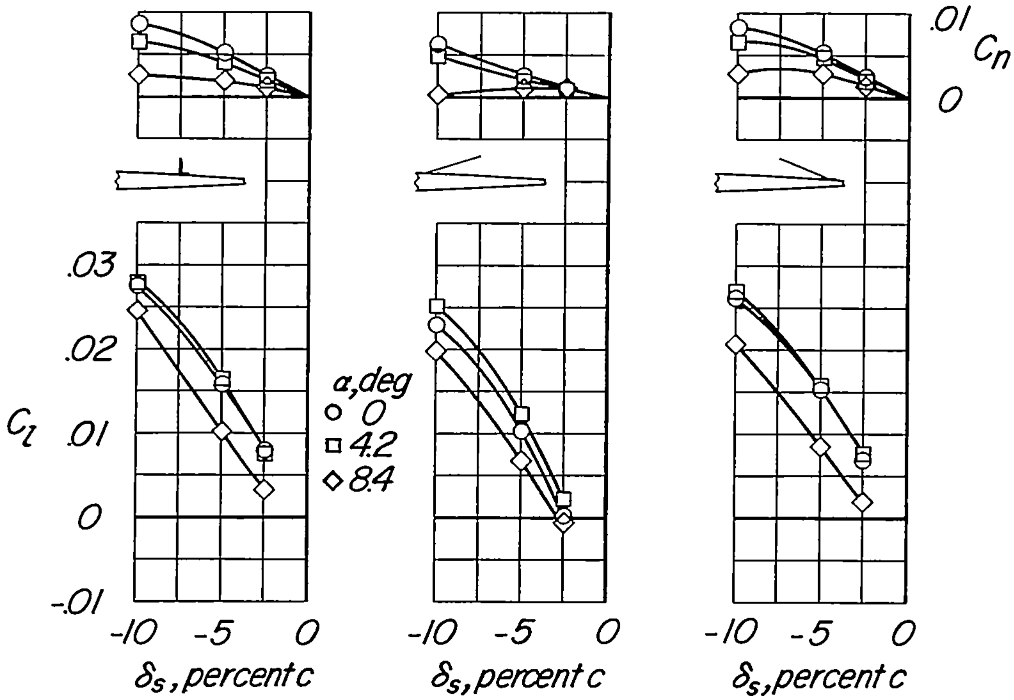
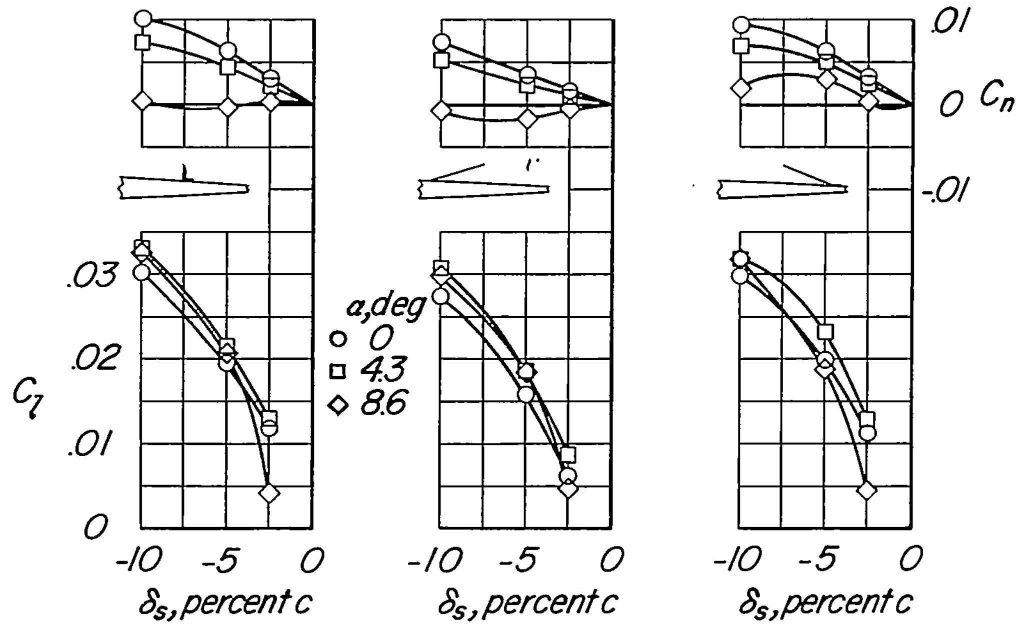


(a) M = 0.59.



(b) M = 0.86.

Figure 8.- Variation of the lateral control characteristics with spoiler projection for several angles of attack. Spoilers 1, 2, and 3.

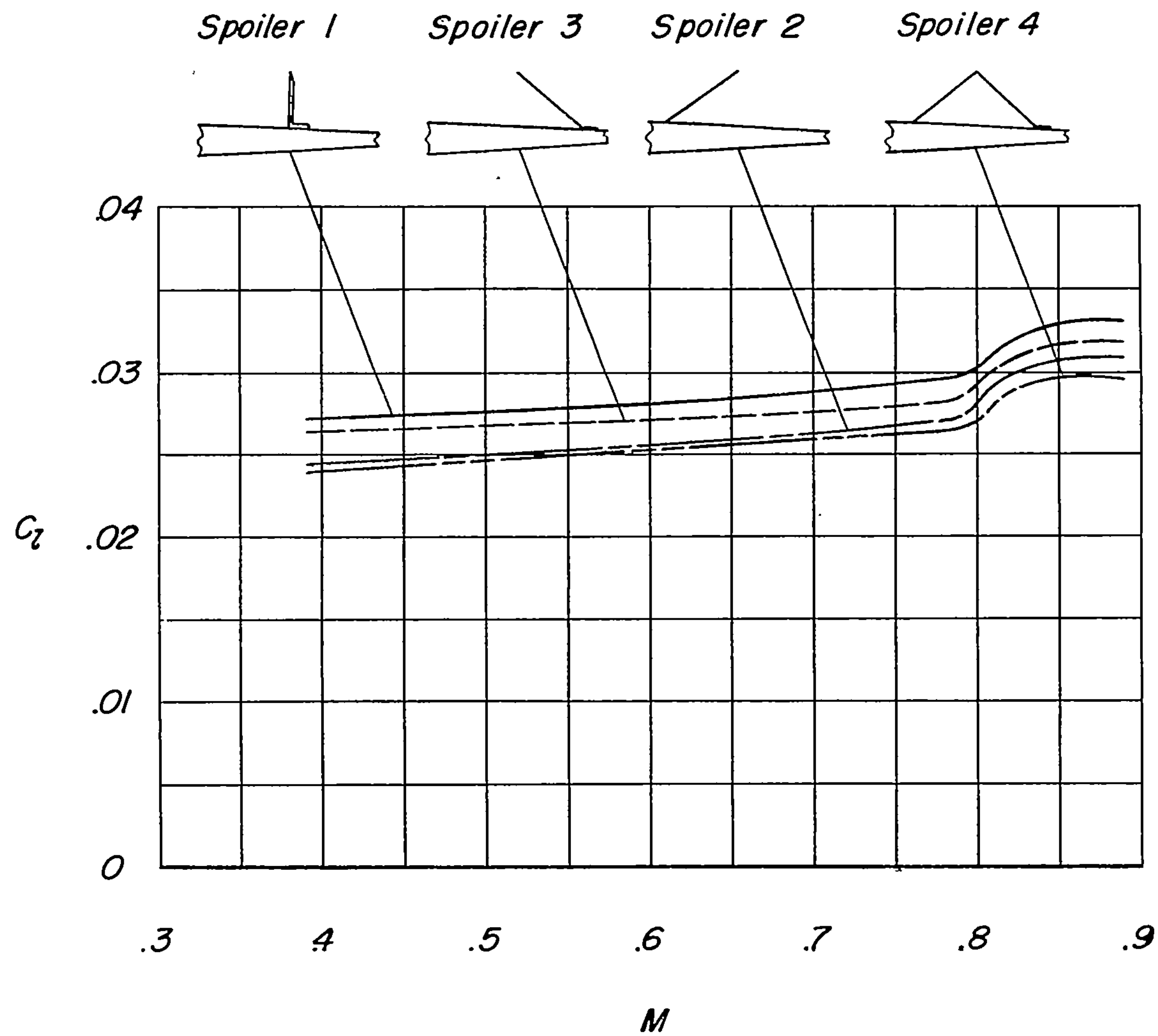


Figure 9.- Variation of rolling-moment coefficient with Mach number for the various spoilers investigated. $\alpha \approx 4^{\circ}$; $\delta_s = -10$ percent c.